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Do students understand the detrimental effects of mind wandering during online learning?

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ABSTRACT

Do students understand the potentially detrimental effects of mind wandering as they are watching a lecture online? To answer this question, we combined methods used to assess mind wandering and metacognitive methods used to assess student's judgments of learning. In two studies, college students watched a video lecture from an online course, and while watching it, responded to standard mind wandering prompts. They then judged how well they would perform on a quiz over the material they had just viewed. Analyses focused on answering two specific questions. Would students' judgments be higher when they reported being on-task than when they reported having task-unrelated thoughts? And, would their judgments be higher when they reported being on-task than when they reported having thoughts about whether they understand the material or reported elaborating on it (which we refer to as *task-related thoughts*)? Across two studies, students' judgments of learning were higher when they reported being on-task than when they reported having task-unrelated thoughts. Judgment magnitude was also greater when students reported task-related thoughts (e.g., assessing their understanding) than task-unrelated thoughts, even though performance did not differ after these two kinds of report. Relevant to instructional applications, students understand that mind wandering may be potentially detrimental to quiz performance, which suggests they may be open to interventions aimed at reducing mind wandering.

1. Introduction

Emma is watching a video online for a class on economics. The professor is energetic, well prepared and knowledgeable, but nevertheless, Emma's mind strays from the video from time to time. One time she is thinking about what she will be doing for dinner, and at another, she wonders how well she is understanding the lecture. Emma is not atypical – such mind wandering is prevalent in day-to-day life (e.g., He, Becic, Lee, & McCarley, 2011; McVay, Kane, & Kwapil, 2009; Song & Wang, 2012) and is rather ubiquitous when students are watching lectures in a classroom or watching videos (e.g., Lindquist & McLean, 2011; Risko, Anderson, Sarwal, Engelhardt, & Kingstone, 2012; Szpunar, Khan, & Schacter, 2013; Unsworth, McMillan, Brewer, & Spillers, 2012; for a review, see; Szpunar, Moulton, & Schacter, 2013). Not only do people mind wander, but when they do, it is often related to poorer performance as compared to when they report being on-task. Consider outcomes from Risko et al. (2012, Experiment 1), who had college students watch a video recording of a lecture on a particular topic, such as psychology or economics. Four times during the lecture, students were probed with the question, "Were you mind wandering?", and after the lecture, a multiple-choice test was administered. Students reported mind wandering prior to 43% of the probes, and across students more mind wandering was related to poorer performance

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on the criterion test ($r = -0.31$).

Despite a growing literature on mind wandering, an essential issue that has not been addressed concerns the degree to which people understand the potentially detrimental effects of mind wandering as it occurs. Thus, in the current research, our main aim was to answer the following questions: Do students believe that they will do more poorly when they are mind wandering than when they are attending to a lecture? And, if they believe that off-task mind wandering hinders their learning, do they also believe that they will do poorly when they are thinking about some other aspects of a course lecture? The latter question is relevant to task-related thoughts, such as when Emma was wondering how well she understood the material. These questions are central to the present research, and we return to them after we discuss how students' beliefs about mind wandering could influence their behavior and learning.

1.1. Metacognition and mind wandering

Whether students understand the possible detriments of mind wandering is important because their beliefs about mind wandering could influence how effectively they regulate their learning. And, according to theories of self-regulated learning, students' beliefs about the effects of mind wandering could ultimately influence how well they learn. In particular, two core components of process-oriented theories of self-regulated learning are metacognitive monitoring and control (e.g., Dunlosky & Ariel, 2011; Winne & Hadwin, 1998; Winne, 2001; for other perspectives on self-regulated learning, see; Zimmerman & Schunk, 2001). Monitoring pertains to students' on-going evaluation of their learning, and control pertains to numerous activities that students engage in to achieve a particular goal (e.g., deciding to review material, using a particular study strategy). Monitoring and control processes can be mutually influential (Nelson & Narens, 1990), such as when students use their monitoring of how well they are learning to control their subsequent study decisions (e.g., Kornell & Metcalfe, 2006; Metcalfe & Finn, 2008; Thiede, 1999; Thiede, Anderson, & Therriault, 2003). For instance, with respect to watching a video of a course lecture, if students judge that mind wandering is detrimental, then when they realize they are mind wandering, they can potentially exert appropriate control to review any material that they believe had been missed. By contrast, if students judge that mind wandering does not have a meaningful impact on learning, they may be less likely to adjust their engagement appropriately when they realize they are mind wandering. In this case, they may simply reorient to the on-going lecture but not review missed material, or they may just continue to mind wander, believing that they can do two tasks (i.e., mind wander and listen to a lecture) relatively well at the same time.

These possibilities, which arise from self-regulation theory, motivate our main question: Do students understand that mind wandering is detrimental to their learning? To answer it, we estimated students' beliefs about the effects of mind wandering by combining standard methods to measure mind wandering (McVay & Kane, 2009) with those that have been used to measure students' evaluations of their learning (Dunlosky, Mueller, & Thiede, 2016). More specifically, college students watched an online video lecture, and during the lecture, they were probed 6 times with the following mind-wandering prompt (adapted from McVay & Kane, 2009, see also Hollis & Was, 2016): "In the last 5 s, what were you just thinking about? (1) The video, (2) How well I'm understanding the video, (3) A memory from the past, (4) Something in the future, (5) Current state of being, (6) Thinking about or using technology, or (7) other." The first response category (# one) indicates students were on-task, whereas the others reflect either some form of task-related thought (e.g., # two) or mind wandering (#s three through seven). After responding to this prompt, the students then made a judgment of learning (JOL), which is a metacognitive judgment that pertains to how well they will perform on an upcoming test (for a recent review, see Rhodes, 2016). In particular, they were asked "How well will you perform on test questions about the last section of material that was just presented?" and answered on a percentage scale (0%, 20%, 40%, et cetera). These JOLs in part tap people's beliefs about how different factors are related to performance (e.g., Dunlosky & Matvey, 2001; Koriat, 1997; Mueller, Dunlosky, & Tauber, 2014), and in the present case, the issue is whether the students' JOLs are higher when they report being on task than when they report mind wandering.

Equally plausible cases can be made for expecting students to demonstrate - versus not to demonstrate - an understanding of the possible effects of mind wandering. Some laboratory research has shown that students' predictions of performance are lower when they expect to be completing two tasks. In particular, Finley, Benjamin, and McCarley (2014) had college students first separately perform two tasks - one was a difficult *n*-back task and another was a computerized manual tracking task. For the former, participants heard a series of numbers and had to indicate whether each number was the same as the number they had heard *n* places ago, where *n* varied from one to three. So, for the sequence, "three, four, two, four" for the final value (four), participants would respond "no" if it were a 1-back task but "yes" if it were 2-back. As *n* increases, the task becomes more difficult. For the latter, participants were required to keep a mouse cursor on a moving target. After practicing each task separately, they then performed the two tasks at the same time. Before the dual-task trials, during which they had to perform both tasks at the same time, the students predicted how well they would perform the tracking task while performing easier (n-back = 1) versus more difficult (n-back = 3) versions of the *n*-back task. Their predictions about performance on the tracking task decreased with the difficulty of the *n*-back task, indicating they did anticipate the costs of multitasking.

People may have relatively accurate beliefs about concurrently performing two external tasks, especially when those tasks are experimentally controlled (as in Finley et al., 2014). By contrast, people's mind wandering is not experimentally controlled and at times may even be viewed as being self-initiated (e.g., Seli, Risko, & Smilek, 2016). At one extreme, students may perceive that they are mind wandering at times when performance would not suffer, such as when they believe the lecture is focusing on less important material. If so, students may believe that mind wandering is not detrimental or at least not detrimental enough to limit their learning. Importantly, a great deal of research has demonstrated numerous metacognitive illusions in which people's JOLs do not reflect the impact that a variable has on performance (for reviews, see Bjork, Dunlosky, & Kornell, 2013; Serra & Metcalfe, 2009). Moreover, results from some studies of multitasking suggest that students are not always clear about the negative impact of multitasking (e.g., Karpinski, Kirschner, Ozer, Mellott, & Ochwo, 2013; Ophira, Nassb, & Wagner, 2009). Thus, it is also possible that students' JOLs will be similar when they report mind wandering and when they report being on-task.

The main aim of the present research was to competitively evaluate these two possibilities – that is, to empirically evaluate whether students judge that mind wandering limits learning. That is, will their JOLs be lower when they report having *task-unrelated thoughts* (henceforth referred to as *TUTs*; see response #s three through seven above) than when they are on task? A secondary aim was to examine students' JOLs for task-related thoughts, such as whether they were assessing whether they understood the video (as indicated by response # two above). In this case, although students are not reporting attending to the video, the video itself is related to the thought. The issue is whether students believe that such task-related thoughts have the same impact as TUTs on subsequent performance. TUTs have been a major focus of research on mind wandering, with reports of task-related thoughts[1] typically being ignored. The reason for ignoring the latter thoughts is principled, because as noted by McVay and Kane (2009), task-related thoughts are an "ambiguous intermediary between on- and off-task thought" (p. 200), and hence it is reasonable to exclude this category of responses from analyses so as to sidestep ambiguous interpretations (McVay & Kane, 2009, 2012; Unsworth & McMillan, 2013). We agree with this decision for research about mind wandering per se, but for the same reason, we disagree with respect to research focused on students' metacognition of mind wandering. In particular, given that this kind of mind wandering is ambiguous to experimenters, it also may be misleading to students. That is, because task-related thoughts are relevant to the to-be-learned content, students may judge them as beneficial to learning, even though these thoughts could reduce students' learning of information in the focal task (e.g., content in a course lecture) and undermine later performance.

1.2. Research overview

Details of the procedure we used to address these issues are presented in Fig. 1. Students watched an 18-min voice over PowerPoint® lecture, which was an authentic video featured in a communication studies course. The video was streamed and presented online. Mind-wandering probes (as described above) were presented at six different times during the video playback. After responding to a probe, students estimated how well they would perform if quizzed on the content of the last section of presented material, which we refer to simply as a judgment of learning (or JOL). At the conclusion of the video, participants also made a global judgment (henceforth, referred to as a global JOL) in which they predicted how well they would perform on the 12-question quiz. Finally, they completed the quiz on the video content.

The outcome relevant to our main question concerned JOLs for the different responses: Will they be higher when students are on-task than off-task? And, will students' JOLs be different (and presumably higher) when they report having task-related thoughts than TUTs? Although we also collected a global JOL, it cannot be used to address our main questions, because the students did not make multiple global JOLs – such as, one that would represent how well they would perform on questions tapping content when they reported being on-task and another global judgment that would represent how well they would perform on questions tapping content when they reported mind wandering. Nevertheless, the global JOLs can provide further evidence concerning the degree to which each student is sensitive to the amount of his or her own mind wandering. If so, a negative correlation will occur between the number of TUTs and global JOLs across participants. And, assuming that TUTs are related to JOLs and to global JOLs, we can estimate the degree to which TUTs explains the relationship between the judgments and quiz performance. This latter analysis will allow us to discover whether individual differences in TUTs can explain why students' JOLs accurately predict quiz performance.

2. Study 1

2.1. Methods

2.1.1. Participants

Ninety-eight undergraduates at a large Midwestern state university received course credit to participate in the study. Students were enrolled in a course in communication studies.

2.1.2. Procedures

Participants watched an 18-min video of a voice over PowerPoint® slide presentation and were quizzed over the video content. During the video, at predetermined intervals, participants received six mind wandering probes, each immediately followed by a JOL. At the conclusion of the video, participants provided a global JOL, and completed an online quiz. Fig. 1 presents the mind wandering probe and JOL schedule, which included six mind wandering probes, six JOLs, a global JOL, and a quiz. Below we describe each component of the mind wandering task.

2.1.2.1. Online video. The 18-min voice over PowerPoint® used in this study was an authentic video featured in a communication studies course. The video is available upon request from the first author. The video was streamed and presented online. Participants

[1] In the mind-wandering literature, such responses have been referred to as task-related interference, but this label may be misleading because it is theory laden (i.e., whether the thought interferes or not is an empirical question) and (according to a reviewer) is misleading because the thought itself is related to the content. Hence, we decided to use the more descriptive label of task-related thought.

	TUT1 JOL1	TUT2 JOL2	TUT3 JOL3	TUT4 JOL4	TUT5 JOL5	TUT6 JOL6	GLOBAL JOL		
Start Video	**3:45** Probe 1 JOL 1	**6:54** Probe 2 JOL 2	**10:24** Probe 3 JOL 3	**12:44** Probe 4 JOL 4	**15:16** Probe 5 JOL 5	**18:05** Probe 6 JOL 6	**18:05** Global JOL	End Video	Quiz
	Pause	Pause	Pause	Pause	Pause	Pause	Pause		

Fig. 1. Overview of procedure.

were encouraged to set aside 20 min to watch the video in one sitting; they were also informed that they would be asked questions during the video and receive a quiz immediately after it. After starting the video, participants could not pause, restart, or stop playback.

2.1.2.2. Mind-wandering probes. Mind wandering probes were presented at six different times during the video playback. When a thought probe was presented, the video stopped and sounded a beep to alert the participant to respond. During each probe, participants were presented with seven possible responses (noted below) and asked to classify their thoughts from the past 5 s.

Using the same classifications as previous research (e.g., Hollis & Was, 2016; McVay & Kane, 2012), response 1 was evaluated as on-task. Responses 3–7 were evaluated as TUTs. Response 2 was evaluated as task-related thoughts.

In the last 5 s, what were you just thinking about?

1) The video.
2) How well I'm understanding the video.
3) A memory from the past.
4) Something in the future.
5) Current state of being. (ex) I'm feeling hungry
6) Thinking about or using another technology. (ex) texting; checking Facebook.
7) Other.

2.1.2.3. JOLs. Immediately after classifying their thinking, participants were asked to estimate how well they would perform if quizzed on the last section of presented material. At each of these JOLs, participants were asked, "*How well will you perform on test questions about the last section of material that was just presented?*" They responded by indicating 0%–100% using 20 point increments (0, 20, 40, 60, 80, or 100). After responding to the question, the video automatically resumed playback.

2.1.2.4. Global JOL. At the conclusion of the video, participants were asked, "*You are about to take a 12-question test over the content of the video. How many questions do you think you will correctly answer?*" They responded by indicating how many correct responses they believed would achieve on the upcoming quiz of the video content (0–12).

2.1.2.5. Quiz. Immediately after making a global JOL, participants then completed the 12-item, online quiz covering the video content. The quiz consisted of 12 multiple-choice questions with four possible responses; two questions were generated from each of the six probe/JOL intervals.

2.2. Results

Participants reported on-task thinking an average of 24.0% of the time and reported TUTs 57.2% of the time. Task-related thoughts accounted for the remaining 18.7% of probe responses. Table 1 presents details regarding the distribution of mind wandering probe responses – 39.8% of the participants did not report being on-task following any of the six probes and only 2.0% of the participants reported being on-task after every probe.

2.2.1. Judgments of learning

Fig. 2 (left panel) presents mean JOLs as a function of students' responses to the mind-wandering probes. To answer our main questions, we conducted two key comparisons: (a) between JOLs when participants reported being on-task versus when they reported TUTs and (b) between on-task JOLs versus when they reported task-related thoughts. Our initial analytic plan involved conducting repeated measures analysis of variance (ANOVA) using mind-wandering probe responses as a within-participant variable. Unfortunately, because most participants did not use all of the response options, most were excluded from the omnibus analyses, leaving only nineteen participants.

Thus, although we begin by reporting the outcomes from the repeated measures ANOVAs, we also conducted a series of paired

Table 1
Proportion and number of probe responses.

Probe Response	Proportion of Participants Reporting 0%	Proportion of Participants Reporting 100%	Number of Participants Reporting at Least Once	Total Proportion of Responses
Study 1				
On-task	.40	.02	59	.24
Task-Related Interference	.46	.01	53	.19
Task Unrelated Thoughts	.09	.14	89	.57
Study 2				
On-task	.39	.02	109	.19
Task-Related Interference: Understanding	.42	.03	103	.16
Task-Related Interference: Related Ideas	.38	.03	110	.17
Task Unrelated Thoughts	.08	.07	163	.48

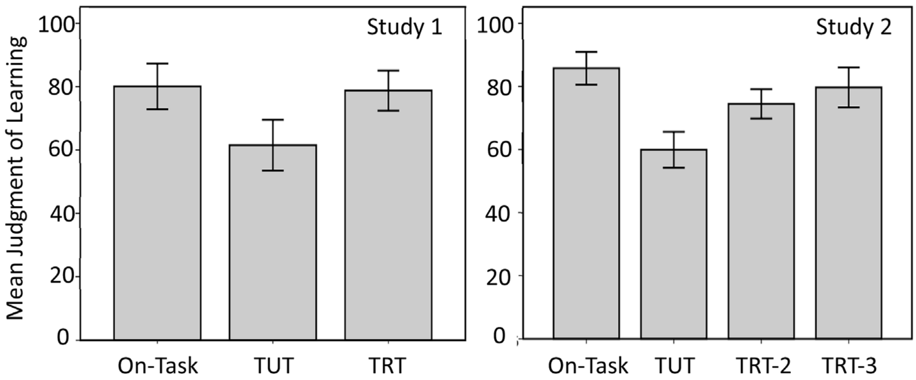

Fig. 2. Mean JOL by Probe Response for Study 1 (left panel) and Study 2 (right panel). In Study 1, the number of participants reporting on task, task-unrelated thoughts (TUT), and task-related thoughts (TRT) were 59, 89, and 52, respectively. In Study 2, the number of participants reporting on task, TUT, TRT probe #2, and TRT probe #3 responses were 109, 163, 110, and 163, respectively.

samples *t*-test in which we compared each of the probe response types to the other and adjusted alpha from .05 to .017 based on the Sidak correction and a series of samples t-tests, treating the response options as a between-participant variable and adjusting our alpha from .05 to .017 based on the Sidak correction. We chose the Sidak correction because it is more accurate and can be calculated for non-independent tests (Abdi, 2007). The independent samples *t*-test do suffer from the flaw of a violation of independent observations, but most important, regardless of how we conducted these inferential statistics, they led to the same statistical conclusions,[2] paralleling the effects that are evident from an examination of Fig. 2. Namely, JOLs were significantly higher when they followed on-task responses than TUT responses; they did not significantly differ following reports on-task responses and task-related thoughts; and, JOLs were significantly higher following task-related thoughts than TUTs.

For Study 1, the omnibus analysis of variance (ANOVA) for JOLs included the thirty participants who used all three of the focal response options (on-task, TUTs, and task-related thoughts). Maulchy's test of sphericity indicated no violation of the assumption that the variance differences in pairs are equal, Mauchly's W = 0.93, χ^2 (2) = 2.05, p = .36. Mulitivariate tests indicate a significant effect of probe response, Wilks' Lamdbda = 0.75, F (2, 28) = 4.50, p = .020, η_p^2 = 0.24. Assuming sphericity, the results indicate a significant within-participant effect, F (2, 28) = 5.74, MSe = 97.15, p = .005, η_p^2 = 0.17. The planned contrasts indicate that JOLs were significantly greater when participants reported being on-task (M = 76.02, SD = 17.28) than experiencing TUTs (M = 68.29, SD = 18.26), F (1, 29) = 7.51, MSe = 238.76, p = .010, η_p^2 = 0.22, and that JOLs were significantly greater when participants reported task-related thoughts (M = 75.46, SD = 14.07) than TUTs, F (2, 28) = 7.93, MSe = 194.78 p = .009, η_p^2 = 0.22. Finally, no difference occurred between JOLs when participants reported being on-task compared to when they reported task-related thoughts, $F < 1$.

Paired samples *t*-tests support these results. Fifty-nine participants responded to the probes both as on-task and TUTs at least once. Mean JOLs were significantly higher when the participant responded as on-task to the probes (M = 75.80, SD = 15.62) than when they responded with TUTs (M = 69.82, SD = 15.81), t (58) = 3.71, $p < .001$, CI [2.75, 9.21], d = 0.47. Forty-six participants responded with TUTs and task-related thoughts at least once each. Mean JOLs were significantly higher when participants responded

[2] Accordingly, we report outcomes from only the paired samples t-tests. Interested readers can obtain outcomes from the independent samples t-tests (that were conducted on all dependent measures in both studies and consistently supported the same conclusions) from the first author.

with task-related thoughts to the probes ($M = 78.66$, $SD = 16.73$) than when they responded with TUTs ($M = 66.92$, $SD = 18.41$), t $(45) = 3.50$, $p = .001$, CI [2.97, 11.01], $d = 0.42$. Finally, thirty-six participants responded to a probe at least one time each as on-task and a task-related thought; the difference for this comparison was not significant, $t < 1$.

2.2.2. Quiz performance

Participants' mean quiz performance was numerically better for content following on-task responses ($M = 0.85$, $SD = 0.19$) than for content when they reported TUTs ($M = 0.72$, $SD = 0.21$) or task-related thoughts ($M = 0.79$, $SD = 0.23$). To investigate if these differences were significant, we conducted a repeated measures ANOVA with orthogonal contrasts using mind wandering probe responses as a within-participant variable. As previously noted, many participants' data were lost due to empty cells and therefore the final number of participants in this analysis is 19. Thus, as with JOLs, we also conducted the critical comparisons using independent samples t-tests, which supported the same conclusions as the omnibus analyses.

Several participants had missing quiz data (due to not responding to a question) and therefore the repeated measures (ANOVA) for quiz performance included the nineteen participants who used all three of the focal response options (on-task, TUTs, and task-related thoughts. Maulchy's test of sphericity indicated a violation of the assumption that the variance differences in pairs are equal, Mauchly's W = 0.44, χ^2 (2) = 13.97, $p < .001$. Mulitivariate tests indicate a significant effect of probe response, Wilks' Lamdbda = 0.66, F (2, 17) = 4.42, $p = .028$, $\eta_p^2 = 0.34$. Using the Greenhouse-Geisser adjustment, tests of within-participant effects were not significant, F (1.28, 23.07) = 2.16, $p = .13$. However, the tests of within-participant contrasts revealed that quiz performance was higher when participants reported being on-task as compared to when reporting TUTs, F (1, 18) = 9.09, $p = .007$, $\eta_p^2 = 0.34$. Quiz performance was not significantly different when participants reported TUTs as compared to task-related thoughts, $F < 1$. Quiz performance was not significantly better following on-task probe responses compared to task-related thoughts, F (1, 18) = 2.28, $p = .149$, $\eta_p^2 = 0.11$.

The numerical values of the paired samples *t*-tests reflect these results (although outcomes were not significant due to decreased power). Mean quiz scores were numerically higher when the participant responded as on-task to the probes ($M = 0.82$, $SD = 0.21$) than when they responded with TUTs ($M = 0.77$, $SD = 0.19$), t (42) = 1.15, $p = .27$, CI [-0.04, 0.13], $d = 0.31$. Mean quiz accuracy was numerically, but not significantly, higher when participants responded as on-task to the probes ($M = 0.82$, $SD = 0.18$) than when they responded with task-related thoughts ($M = 0.76$, $SD = 0.23$), t (25) = 1.50, $p = .15$, CI [-0.02, 0.14], $d = 0.29$. Mean quiz accuracy was not different when participants responded with task-related thoughts to the probes ($M = 0.75$, $SD = 0.22$) than when they responded with TUTs ($M = 0.71$, $SD = 0.19$), t (41) = 0.80, $p = .43$, CI [-0.06, 0.13], $d = 0.20$.

2.2.3. Relationships between TUTs, JOLs, and quiz performance

To further examine the relationship between TUTs, JOLs, and performance, we conducted correlational analyses among these variables (number of TUTs, mean of the six JOLs, global JOLs, and mean quiz performance). First, the total number of reported TUTs was negatively correlated to both the mean of the JOLs following each probe, $r = -.37$, $p < .001$, and the global JOL, $r = -0.33$, $p = .001$. That is, as compared to students who reported fewer TUTs, those who reported having more also judged that they had learned the content less well.

This relationship between mean JOLs and TUTs, which are the focus of the present research, is highlighted in the scatterplot in Fig. 3 (left panel), which illustrates several key points. First, the significant correlation reported above does capture essentially a linear relationship between the two variables. Second, except for the few participants who reported no TUTs, the spread of JOL values within each TUT category is as large as the average spread across all values, indicating that JOLs are influenced by more than off-task thoughts in this task. We will return to this issue in the General Discussion. Third, mean JOLs and the global JOL were both related to the total quiz score, $r = .36$, $p < .001$, and $r = 0.42$, $p < .001$ (respectively), indicating that individual differences in judgments aligned with actual differences on quiz performance. A key question now is, given that TUTs account for individual difference in how students judge their learning, could this measure of mind wandering explain the relationship between JOLs and quiz performance? In this case, the answer is “no”, because individual differences in the number of TUTs did not significantly predict quiz performance, $r = 0.06$, $p = .59$.

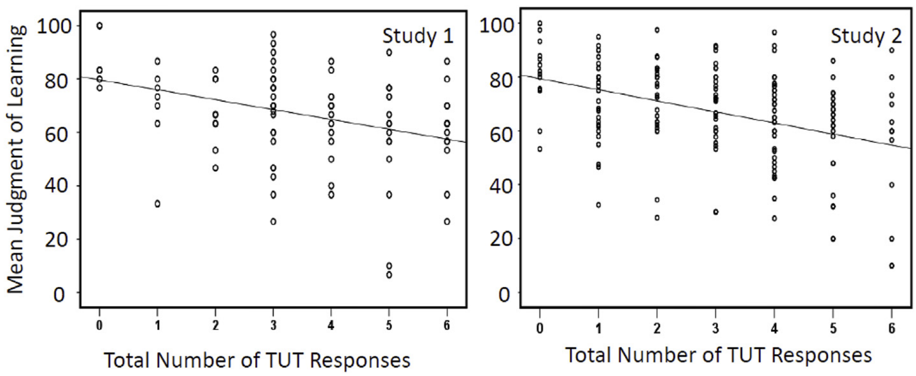

Fig. 3. Mean content JOLs by total TUT responses.

2.3. Discussion

The results from Study 1 are consistent with the hypothesis that participants believed that mind wandering during an online lecture is detrimental to performance on a quiz covering the content from that lecture. By contrast, as compared to JOLs when students reported being off-task, students judged that task-related thoughts would lead to higher levels of performance (see two right-most bars, Fig. 2, left panel). In this case, however, students did not perform better when they had reported task-related thoughts as when they reported TUTs. Given that JOLs were higher after task-related thoughts than TUTs, these outcomes appear to reflect a metacognitive illusion in which students' mistakenly believe that task-related thoughts will improve performance as compared to being entirely off task.

3. Study 2

Given the importance of replication (Pahsler & Harris, 2012), we attempted to replicate the key findings from Study 1 as well as to extend them in Study 2. Concerning the extension, we expanded the probe responses for task-related thoughts. In particular, the probe response used in Study 1 relevant to task-related thoughts focused on whether students were monitoring their understanding of the video. Given our current interest in students' JOLs after task-related thoughts, we retained this probe response but also included a new response: *Something related to the video. (ex) class materials; a previous part of the video; an example*. These task-related thoughts do not reflect student monitoring but instead they capture whether students are thinking about material that is related to the focal lecture. The main reason for including this particular response option was that this kind of mind wandering – about the lecture itself – may be common in educational settings. In Study 1, if the students were thinking about the lecture at times, they would have had to either misclassify their thoughts or use the "other option". Thus, by including this new response option, our aim was to enhance the validity of the mind-wandering probe in the current context.

3.1. Methods

3.1.1. Participants

In total, 178 undergraduates at a large Midwestern state university received course credit to participate in the study. Students were enrolled in an undergraduate course in communication studies.

3.1.2. Procedures

The procedures used in Study 2 were the same as those in Study 1 with one exception. The mind wandering probe response options included a new choice designed to capture elaborative task-related thoughts. The new mind wandering probes read:

In the last 5 s, what were you just thinking about?

1) The video.
2) How well I'm understanding the video.
3) Something related to the video. (ex) class materials; a previous part of the video; an example
4) A memory from the past.
5) Something in the future.
6) Current state of being. (ex) I'm feeling hungry
7) Thinking about or using another technology. (ex) texting; checking Facebook.
8) Other.

3.2. Results

Participants reported on-task thinking an average of 19.1% of the time and reported task unrelated thoughts 48.2% of the time. Concerning task-related thoughts, they reported evaluating their understanding (response # two) or thinking about something related to the video (# two) to 15.8% and 16.8% of probe responses, respectively. Table 1 (bottom panel) presents details regarding the distribution of mind wandering probe responses. 38.8% of the participants did not report being on-task following any of the six probes and only 1.7% of the participants reported being on-task after every probe. These outcomes closely reflect those from Study 1.

3.2.1. Judgments of learning

Fig. 2 (right panel) presents mean JOLs as a function of response to the mind wandering probes. As noted previously, for the inferential analyses, we combined response numbers two (monitoring) and three (thinking about the lecture) into a single variable (referred to as *task-related thoughts*), although mean JOLs to these responses are presented separately in Fig. 2 (labelled as TRT-2 and TRT-3, respectively). To examine if participants' JOLs were related to their reports of mind wandering, our analytical plan was to conduct a repeated measures ANOVA with orthogonal contrasts using the probe responses as a within-participant variable. As in Study 1, due to the number of empty cells (i.e., the lack of all participants, using all probe responses), only 81 participants were included in the within-participant contrasts. Thus, to provide answers to our main questions, we again also reported paired samples t-tests, which supported the same conclusions as the within-participant contrasts.

For Study 2, we conducted a repeated measures ANOVA with planned comparison using probe responses as a within-participant variable (data were dropped from analyses if a participant did not use all probe responses; $n = 81$ for the following analyses). Maulchy's test of sphericity indicated no violation of the assumption that the variance differences in pairs are equal, Mauchly's W = 0.97, χ^2 (2) = 2.76, $p = .25$. Mulitivariate tests indicate a significant effect of probe response, Wilks' Lamdbda = 0.75, F (2, 79) = 21.09, $p < .001$, $\eta_p{}^2 = 0.35$. Assuming sphericity, the results indicate a significant within-participant effect, F (2, 79) = 24.01, $MSe = 75.36$, $p < .001$, $\eta_p{}^2 = 0.23$. Most important, the planned contrasts indicate that JOLs were significantly greater when participants reported being on-task ($M = 81.05$, $SD = 14.95$) than with TUTs ($M = 71.83$, $SD = 14.56$), F (1, 80) = 42.49, $MSe = 162.25$, $p < .001$, $\eta_p{}^2 = 0.35$. JOLs were also significantly greater when participants reported task-related thoughts ($M = 78.22$, $SD = 13.77$) than TUTs, F (1, 80) = 19.84, $MSe = 166.99$, $p < .001$, $\eta_p{}^2 = 0.20$.

Ninety-five participants responded with on-task and TUTs. Mean JOLs were significantly higher when participants responded being on task ($M = 80.56$, $SD = 15.12$) than with TUTs ($M = 70.23$, $SD = 15.29$), t (94) = 7.90, $p < .001$, CI [7.73, 12.92], $d = 0.69$. Ninety-two participants responded to a probe at least one time each as on-task and task-related thoughts. Mean JOLs were significantly higher when participants responded as being on-task ($M = 82.05$, $SD = 14.66$) than with task-related thoughts ($M = 78.88$, $SD = 13.40$), t (91) = 2.85, $p = .005$, CI [0.96, 5.38], $d = 0.022$. One hundred and thirty-six participants responded TUTs and task-related thoughts at least once each. Mean JOLs were significantly higher when participants responded with task-related thoughts ($M = 75.12$, $SD = 15.71$) than with TUTs ($M = 67.81$, $SD = 14.47$), t (135) = 6.66, $p < .001$, CI [5.14, 9.48], $d = 0.57$.

3.2.2. Quiz performance

Quiz performance differed little across the mind wandering probe responses. Contrary to the numerical results of Study 1, as a group, participants' performance, as measured by mean accuracy, did not differ for content following on-task responses ($M = .64$, $SD = 0.33$) than for content when they reported being TUTs ($M = 0.64$, $SD = 0.25$) and was slightly lower than following reports of task-related thoughts ($M = 0.68$, $SD = 0.27$).

We conducted a repeated measures ANOVA with orthogonal contrasts using mind wandering probe responses as a within-participant variable (as for the analysis of JOLs, data were dropped from analyses if a participant did not use all probe responses; $n = 81$ for the following analyses). Maulchy's test of sphericity indicated no violation of the assumption that the variance differences in pairs are equal, Mauchly's W = 0.95, χ^2 (2) = 3.70, $p = .16$. Mulitivariate tests did not indicate significant effect of probe response, Wilks' Lamdbda = 0.98, $F < 1$. Tests of within-participant effects ($F < 1$) and within-participant contrasts (on-task vs. TUTs: $F < 1$) and TUTs vs. TRIs [F(1, 80) = 1.46, $p = .23$) were also non-significant.

Mean quiz scores were numerically, but not significantly higher when the participant responded as on-task to the probes ($M = 0.65$, $SD = 0.34$) than when the responded with TUTs ($M = 64$, $SD = 0.27$), t (65) = 0.15, $p = .88$, CI [-0.09, 0.11], $d = 0.03$. Mean quiz accuracy was not significantly higher when the participant responded as on-task to the probes ($M = 0.63$, $SD = 0.33$) than when they responded with task-related thoughts ($M = 0.69$, $SD = 0.24$), t (67) = -1.39, $p = .17$, CI [-0.17, 0.03], $d = 0.21$. Mean quiz performance were not different when the participant responded with task-related thoughts to the probes ($M = 0.68$, $SD = 0.28$) than when the responded with TUTs ($M = 0.65$, $SD = 0.26$), t (97) = 0.90, $p = .37$, CI [-0.04, 0.10], $d = 0.11$.

3.2.3. Relationships between TUTs, JOLs, and quiz performance

The relationships among TUTs, JOLs, and quiz performance replicated those from Study 1. In particular, the total number of reported TUTs was negatively correlated to both the mean of the JOLs, $r = -0.46$, $p < .001$, and the global JOL, $r = -0.30$, $p < .001$. And, as shown in Fig. 3 (right panel), the relationship between JOLs and TUTs was similar to that found in Study 1. The mean of the six JOLs and the global JOL were both related to the total quiz score, $r = 0.24$, $p = .001$, and $r = 0.25$, $p = .001$ respectively. Individual differences in TUTs, however, did not predict differences in quiz performance, $r = -0.07$, $p = .33$.

3.3. Discussion

The key results relevant to JOLs from Study 2 replicate those of Study 1. Namely, participants expected mind wandering would be detrimental to performance. In the present case, however, their judgments were not correct, because an unexpected result was the lack of difference in quiz accuracy in relationship to the different probe responses. We are unsure why quiz accuracy was not higher after on-task responses than TUTs (as it was in Study 1), and the general lack of relationship between TUTs and quiz performance across participants (as per correlational results) was also unexpected. Given this limitation concerning quiz performance, an informative avenue for future research would be to investigate JOLs across a variety of tasks that would be differentially influenced by TUTs. The question here would be the degree to which JOLs track how much (and when) TUTs actually undermine performance. With this limitation of Study 2 in mind, however, the overall results indicate that the participants' JOLs are not accurately tracking how well they had learned the material; that is, as in other contexts, their JOLs do not reflect direct access to how well the content is represented in long-term memory (e.g., Koriat, 1997). Instead, the JOLs may reflect their beliefs that mind wandering can interfere with learning from an online video.

4. General discussion

To investigate metacognition and mind wandering in the present studies, we used materials that represented those used in educational settings – at the time these studies were conducted, the video was being used in an online course. Hollis and Was (2016) investigated mind wandering with similar course materials (two online videos with an instructor lecturing on-camera), and participants reported being off-task 43% of the time. Consistent with this approach, the online voice-over slide presentation used in the present studies produced a great deal of mind wandering; across both studies, students reported off-task thinking more than 48% of the time. Importantly, such mind wandering allowed us to answer our two main questions. Will students judge that their learning is better when they were on-task than off-task? And, will students judge they are learning more when they are having task-related thoughts than when they report having TUTs? In the remainder of the General Discussion, we discuss evidence relevant to each question in turn.

4.1. Do students believe mind wandering is detrimental to learning?

As illustrated in Fig. 2, students made higher JOLs following reports of being on-task than following reports of experiencing TUTs, and this relationship represents a medium effect size (as indicated by Cohen's *d*s above .50 and η_p^2 greater than 0.20 in both studies). Moreover, the amount of TUTs was negatively related to JOLs across participants (Fig. 3): 20% or more of the variance in JOLs was accounted for by mind wandering probe responses across the studies. These outcomes converge on the conclusion that college students believe that mind wandering is detrimental to their learning of lecture content when watching an online video.

The present conclusion that students believe that mind wandering is detrimental to task performance appears to contradict claims that students are sometimes unaware of the detrimental effects of multitasking (e.g., Karpinski et al., 2013; Ophira et al., 2009). For instance, Ophira et al. (2009) reported that self-reported multitaskers had more difficulty filtering non-essential information (and had lower task-switching accuracy) than did their non-multitasking counterparts. Findings such as these suggest that students are unaware of the deficits caused by multitasking. The methods used in these studies on multitasking differ in numerous ways from methods used in research on mind wandering, and any number of these may explain differences in conclusions. First, one possibility pertains to differences in measurement; that is, whether questionnaires were used to survey students' beliefs about multi-tasking (as in prior research on multitasking) or whether (as in the present studies) students' beliefs were tapped indirectly by asking them to make metacognitive predictions (i.e., JOLs). Another possible explanation about differences in conclusions is whether people self-initiate the multi-tasking. In particular, when people self-initiate multi-tasking, the goal is to attempt to successfully perform two activities, and by intentionally switching back and forth, people may perceive that they are managing both tasks well. By contrast, in studies on mind wandering, the mind wandering in many cases may not be self-initiated; instead, thoughts may spontaneously become active in working memory (McVay & Kane, 2009) and hence may be perceived as intrusive. Although both possibilities require further evaluation, evidence from Finley et al. (2014) discussed earlier suggests that differences in measurement are partly responsible, because they found that students' predictions reflected multi-tasking *costs*. Moreover, recent studies on multi-tasking have reported that students understand that even multi-tasking can impair performance in some contexts (e.g., Atchley, Atwood, & Boulton, 2011; Finley et al., 2014; Gingerich & Lineweaver, 2014; Harrison, 2011). Altogether, the extant evidence (and differences in conclusions) highlight that an important avenue for future research will be to discover why (and under what conditions) people believe that mind wandering (and multi-tasking) will negatively impact their performance.

One other outcome is noteworthy, although it was less relevant to our main aims. Even though the number of TUTs did account for variance in JOLs, it is equally evident that other factors influenced the level of JOLs; as shown in Fig. 2, within each level of TUTs, individual differences in JOL magnitude were extensive. This unexplained variance may arise from differences in the magnitude of mind wandering, from differences in a priori content knowledge, how fluently students were processing the lecture when they were on-task, among many other factors (for reviews, see Dunlosky, Mueller, & Tauber, 2014; Rhodes, 2016). Discovering how mind wandering interacts with these other factors to influence students' JOLs may further reveal students' beliefs about memory and learning as well as support prescriptions for improving the accuracy of students' JOLs. Steps toward such discovery may be made in part by adapting the current methods, which use online data videos to collect data in a context that is relevant to real-life education.

4.2. Do students believe having task-related thoughts is detrimental to learning?

According to the Concerns X Control Failures theory (McVay & Kane, 2009; 2012), when students have control failures while performing a task, they focus on the stream of on-going concerns instead of the task-related information. For this theory, mind wandering results from two influences: (1) the presence of spontaneously generated thoughts cued by environmental stimuli (concerns) and (2) the lack of executive control to inhibit interference from the spontaneously generated thoughts. In the present case, two categories of concerns were TUTs and task-related thoughts, and it turns out, students did not judge them equally. As evident from inspecting Fig. 2, students' JOLs were lower following reports of TUTs than following reports of thinking of something related to the lecture (i.e., task-related thoughts), even though performance did not significantly differ after the two kinds of report.

These outcomes suggest that students do not perceive all mind wandering in the same way – students believe that being totally off-task is worse than thinking about some aspect of the on-going task. One possibility is that if any thought from the stream of mind wandering overlaps with the content of the on-going task, then people will not view the mind wandering as detrimental to the on-going task. Consistent with this possibility (right panel, Fig. 2, Study 2), students' JOLs did not differentiate between when they were elaborating on content and when they were monitoring their understanding of it. In educational settings, different kinds of task-related thoughts may be especially prevalent (e.g., with the present online videos) because students are often encouraged to think about what they are learning as they are trying to learn it. Thus, understanding how these kinds of task-related thoughts relate to students' JOLs and performance is important for future applied and theoretical research.

4.3. Closing remarks

Students do believe that mind wandering can undermine their learning while watching an on line video, which may be beneficial to helping them to abate mind wandering. For instance, mindfulness training has shown promise for reducing students' mind wandering and improving their performance (Mrazek, Franklin, Phillips, Baird, & Schooler, 2013). Also, at least one instructional technique (i.e., in-class quizzing) has been shown to reduce mind wandering and improve learning (Szpunar et al., 2013). Thus, teachers may get leverage and student buy-in for using in-class testing if teachers explain how intermittent testing can not only boost their learning of the tested material but reduce their mind wandering. Of course, these applications should be considered preliminary, given that these are the first studies to explore the relationship between TUTs and students' JOLs. As such, evaluating the degree to which students' JOLs reflect understanding of mind wandering in other contexts is an important agenda for research on metacognition and mind wandering.

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